APPENDIX 3

Robust Summaries for Petroleum Gases

Consortium Registration # 110997

Explanatory Note for Robust Summary Format

The Petroleum HPV Testing Group has elected to use the IUCLID (International Uniform Chemical Information Database) database as the repository for robust summaries for this program. IUCLID has been structured to accommodate a wide variety of data so that it can be used as a repository for all available data on any given chemical or category of chemicals. Many of the data elements (*e.g.* OECD company location and production information, packaging information, emergency procedures, etc.) are outside the SIDS (Screening Information Data Set) requirements of the US HPV Chemical Challenge. Consequently, only those fields relevant to existing data and proposed testing in support of the Petroleum Gases Test Plan are presented in this document.

ROBUST SUMMARY
OF INFORMATION ON

Substance Group # PETROLEUM GASES

Summary prepared by American Petroleum Institute

Creation date	**2 NOVEMBER 1999**
Printing date:	**15 AUGUST 2000**
Date of Last Update:	**15 AUGUST 2000**

NB. Reliabiliy of data included in this summary has been assessed using the approach described by Klimisch et al.

Klimisch, H. J., Andreae, M. and Tillman, U, (1997)
A systematic approach for evaluating the quality of experimental toxicological and ecotoxicological data.
Regulatory Toxicology and Pharmacology 25, 1-5.

1.1 GENERAL SUBSTANCE INFORMATION

Substance type: Petroleum product
Physical status: Gaseous

Petroleum gases are obtained from natural gas processing and petroleum refining operations. They are typically Class II substances on the TSCA Inventory which are "Chemical Substances of Unknown or Variable Composition, Complex Reaction Products, and Biological Materials." Their toxicity may be assessed from a consideration of the toxicity of the individual components.

This summary includes the available information on the following components:

Methane
Ethane
Propane
normal Butane
iso Butane

Where available, physico-chemical data are also included for normal and iso-pentane.

For information on published reviews of information available on other individual hydrocarbons, which may be components of petroleum gas, see **Section 1.17**.

1.2 SYNONYMS

Petroleum gas
Liquefied petroleum gas
LPG

1.8 OCCUPATIONAL EXPOSURE LIMIT VALUES

Type of limit: TLV (US)
Limit value: 1000 ppm for LPG
Schedule: 8 hour(s)
Remark: In addition to the TLV established for LPG by the ACGIH, they have also established TLVs for the following hydrocarbons that are likely to be present in petroleum gas:

Methane	No TLV	listed as a simple asphyxiant
Ethane	No TLV	listed as a simple asphyxiant
Propane	2500 ppm	critical effect simple asphyxiant
Butane	800 ppm	critical effect narcosis
Pentane (all isomers)	600 ppm	critical effects irritation and narcosis.

(1)

1.17 REVIEWS

Reviews have been prepared on n-Pentane and 1,3-butadiene.
In addition a review of the available toxicological information on 9 individual hydrocarbons has also been published.

(7, 9, 19, 20)

2.1 MELTING POINT

Value: -189.7 to -130° C
Decomposition: no
Sublimation: no
GLP: no data
Remark: Values given above span the range for the hydrocarbons that may be present in Petroleum gas. Values for the individual hydrocarbons are as follows:

Methane	-182°C
Ethane	-183.3°C
Propane	-189.7°C
n-Butane	-138.4°C
iso-Butane	-159.4°C
n-Pentane	-130°C
iso-Pentane	-159°C

Reliability: 1, valid without restriction. Data are taken from the CRC Handbook of chemistry and physics

(8)

2.2 BOILING POINT

Value: -164 to -0.5° C at 1013 hPa
Decomposition: no
GLP: no data
Remark: Values given above span the range for the hydrocarbons that may be present in Petroleum gas. Values for the individual hydrocarbons are as follows:

Methane	-164°C
Ethane	-88.6°C
Propane	-42.1°C
n-Butane	-0.5°C
iso-Butane	-11.7°C
n-Pentane	-36.1°C
iso-Pentane	-27.8°C

Reliability: 1, valid without restriction. Data are taken from the CRC Handbook of chemistry and physics.

(8)

2.3 DENSITY

Type: Relative density
Value: 0.3 to 0.584
GLP: no data
Remark: Relative densities given above span the range of values for the hydrocarbons (liquid) that may be present in Petroleum gas. Relative densities (15/15°C) of the individual liquid hydrocarbons are:

Methane	0.3 (estimated)
Ethane	0.35619
Propane	0.50698
n-Butane	0.58402
iso-Butane	0.56286
n-Pentane	0.63108

Reliability: 4, not assignable

(11)

2.4 VAPOUR PRESSURE

Value: 1147 to 350000 hPa
GLP: no data
Remark: Values given above span the range of values for the individual hydrocarbons that may be present in Petroleum gas. Values for the individual hydrocarbons are shown below.
The units are given as hPa (abs) @313.15K

Methane	350000 (estimated)
Ethane	60000 (estimated)
Propane	13698
n-Butane	3796.1
iso-Butane	5308.9
n-Pentane	1147
iso-Pentane	1513.1

Reliability: 4, not assignable

(11)

2.5 PARTITION COEFFICIENT

log Pow: ≤ 2.3
Year: 1993
GLP: no data
Remark: Measured values have been taken from the Pomona College Log Pow Data Base.
Log Pow values for the individual hydrocarbons that may be present in Petroleum gas are:

Propane	2.3
n-Butane	2.8
iso-Butane	2.8

Reliability: 4, not assignable. Data taken from an on-line database.

(17)

2.6.1 Water Solubility

No data

2.7 Flash Point

Value: Approx. –60° C
GLP: no data
Remark: Flash points for the individual hydrocarbons that may be present in Petroleum gas are as follows:

Hydrocarbon	Flash Point (°C)
Methane	-187.78
Ethane	-135
Propane	-104.44
n-Butane	-60
iso-Butane	-82.7

Reliability: 4, not assignable

(23)

2.8 AUTO FLAMMABILITY

Value: 410 to 540° C
GLP: no data
Remark: Autoignition temperatures for the individual hydrocarbons that may be present in Petroleum gas are as follows:

Hydrocarbon	Autoignition Temperature (°C)
Methane	540
Ethane	515
Propane	450
n-Butane	405
iso-Butane	462

Reliability: 4, not assignable

(16)

2.9 FLAMMABILITY

Extremely flammable

2.10 EXPLOSIVE PROPERTIES

Remark: UELs and LELs for the individual hydrocarbons that may be present in Petroleum gas are as follows:

	LEL (%vol)	UEL (%vol.)
Methane	5.0	15
Ethane	3.0	12.5
Propane	2.12	9.35
n-Butane	1.86	8.41
iso_Butane	1.8	8.44
n-Pentane	1.4	7.8
iso-Pentane	1.32	-

Reliability: 1, valid without restriction. Data are taken from the CRC Handbook of chemistry and physics.

(8)

3.1.1 Photodegradation

Type: Air
Light source: Sun light
INDIRECT PHOTOLYSIS
Sensitizer: OH
Conc. of sens.: 1000000 molecule/cm^3
Method: Calculated according to Atkinson 1990
GLP: no
Test substance: Methane, ethane, propane, n-butane and iso-butane.

Result: Atkinson gives rate constants which enable half lives to be calculated for degradation of hydrocarbons in contact with hydroxyl radicals in the troposphere, under the influence of sunlight. The calculated half lives for the components of petroleum gas are as follows:

Constituent	Half Life (Days)
Methane	960
Ethane	30
Propane	7
Isobutane	3.4
n-butane	3.2

Reliability: 4, not assignable. Calculations were made using the constants listed in reference by Atkinson.

(4)

3.1.2 Stability in Water

Not applicable

3.1.3 Stability in Soil

Not applicable

3.2 MONITORING DATA (ENVIRONMENT)

3.3.1 Transport between Environmental Compartments

Type: volatility
Remark: In the event of an accidental release of any of the C_1 to C_4 hydrocarbons to the environment, all of the material will end up in the air compartment due to the volatility of the hydrocarbons.

3.3.2 Distribution

Media: air - biota - sediment(s) - soil - water
Method: Calculation according Mackay, Level I
Method: Distribution has been calculated according to Mackay Level 1. using parameters defined by van der Zandt and van Leeuwen.

Result: Results for the C_1 to C_4 hydrocarbons are as follows:

C_1 to C_4 Hydrocarbons	Air (%)	Water (%)	Soil (%)	Sediment (%)	Suspended matter (%)	Biota (%)
	100	0	0	0	0	0

(18, 27)

3.4 MODE OF DEGRADATION IN ACTUAL USE

Petroleum gases used as fuels are burnt to yield mainly carbon dioxide, carbon monoxide and water vapour. When the unburned hydrocarbons enter the atmosphere they are photodegraded by reaction with hydroxyl radicals. See section 3.1.1.

(3)

3.5 BIODEGRADATION

Type: aerobic
Inoculum: adapted microorganisms
Degradation: 76.2 % after 35 day
Result: inherently biodegradable
Year: 1963
GLP: no data
Test substance: Methane
Method: The 35 day BOD was determined at 25°C using 1.0 mg of methane and mixed cultures of hydrocarbon oxidising bacteria. The hydrocarbon was dispersed in the BOD solution by adsorption on ignited sand. No further details of the test method are provided.

Reliability 4, not assignable. Insufficient information given in the publication.

(30)

Type: aerobic
Inoculum: adapted microorganisms
Degradation: 65.7 % after 35 day
Result: inherently biodegradable
Year: 1963
GLP: no data
Test substance: Ethane
Method: The 35 day BOD was determined at 25°C using 1.0 mg of ethane and mixed cultures of hydrocarbon oxidising bacteria. The hydrocarbon was dispersed in the BOD solution by adsorption on ignited sand. No further details of the test method are provided.

Reliability: 4, not assignable. Insufficient information given in the publication.

(30)

3.8 ADDITIONAL REMARKS

The ability of bacteria to use C_1 to C_4 hydrocarbons as a carbon source has been demonstrated in a number of studies.

Fuerst & Stephens demonstrated that *Methylococcus* and other cultures were able to use methane as a carbon source. Also, organisms such as *Neurospora crassa* were able to grow utilizing ethane. Stephens et al. have also shown that butane supports the growth of *N. crassa*.

O'Brien & Brown showed that both butane and iso-butane support growth *of Mycobacterium phlei* and also that butane supports the growth of *Mycobacterium crassa*.

Vestal and Perry found that ethane, propane and butane promoted the growth of *Mycobacterium vaccae*, suggesting that these hydrocarbons are biodegradable.

In contrast, studies by Wanatabe & Takesue and by Rode & Foster have shown that butane is also able to inhibit the growth of certain bacteria, moulds, fungi and plant seeds.

(10, 21, 22, 25, 28, 29)

AQUATIC ORGANISMS

4.1 ACUTE/PROLONGED TOXICITY TO FISH

Exposure period:	96 hour(s)
Unit:	mg/l
TLM96 :	> 1000
GLP:	no data
Test substance:	Methane, propane and butane
Remark:	The value is cited in Patty, but it has not been possible to obtain the original reference. The basis for this value, therefore, is not clear. Furthermore, it is now considered that aquatic toxicity of petroleum gases is not applicable.
Reliability:	4, not assignable. This information is not reliable.

(23)

4.2 ACUTE TOXICITY TO AQUATIC INVERTEBRATES

Not applicable

4.3 TOXICITY TO AQUATIC PLANTS E.G. ALGAE

Not applicable

4.4 TOXICITY TO MICROORGANISMS E.G. BACTERIA

See section 5.5 below

4.5 CHRONIC TOXICITY TO AQUATIC ORGANISMS

Not applicable

5.1 ACUTE TOXICITY

5.1.1 Acute Oral Toxicity

Not applicable

5.1.2 Acute Inhalation Toxicity

Type:	LC_{50}
Species:	rat
Sex:	male/female
Number of Animals:	6
Vehicle	substance administered with air
Exposure time:	15 minute(s)
Value:	> 800000 ppm [≡ 1,442,847 mg/m^3]
Year:	1982
GLP:	no data
Test substance:	Propane, purity not specified
Test condition:	Propane was passed through a calibrated rotameter and mixed with the required amount of air. As soon as the concentration of propane exceeded 25%, oxygen was mixed with the air to maintain an oxygen concentration of 20%.
Method:	Groups of either 6 male or 6 female rats were exposed for 15 minutes in 500-ml whole body inhalation chambers. The animals were observed for effects on the CNS over a 10-minute exposure period. The EC_{50} CNS effect concentration (10-min) was calculated. The concentrations causing death after 15 minutes exposure were recorded and the LC_{50} (15-min) was calculated. A range of concentrations was used such that the no effect concentration, the 100% effect concentration and several in-between concentrations were determined. [Details of actual concentrations are not provided].
Result:	Propane caused CNS depression. Signs of intoxication were slight ataxia, loss of righting reflex, loss of movement, narcosis, shallow respiration and death eventually from respiratory depression. Recovery from a non-lethal exposure was rapid and the rats appeared normal within 10 minutes. Where death occurred, it was during exposure, never afterwards. The calculated EC_{50} and LC_{50} values with 95% confidence limits, expressed as concentrations in air are as follows: EC_{50} (CNS depression, 10 min.) 280000 (220000-350000) ppm [≡ 504,996 (396,783-631,245) mg/m^3] LC_{50} (15 min.) >800000 ppm [≡ 1,442,847 mg/m^3]
Reliability:	2, valid with restrictions. Study not performed to guidelines and some experimental details lacking.

(6)

5. Toxicity

Type:	LC_{50}
Species:	rat
Sex:	male/female
Number of Animals:	6
Vehicle:	substance administered with air
Exposure time:	15 minute(s)
Value:	570000 ppm [≡ 1,355,015 mg/m^3]
Year:	1982
GLP:	no data
Test substance:	Isobutane, purity not specified
Test condition:	Isobutane was passed through a calibrated rotameter and mixed with the required amount of air. As soon as the concentration of isobutane exceeded 25%, oxygen was mixed with the air to maintain an oxygen concentration of 20%.
Method:	Groups of either 6 male or 6 female rats were exposed for 15 minutes in 500-ml whole body inhalation chambers. The animals were observed for effects on the CNS over a 10-minute exposure period. The EC_{50} CNS effect concentration (10-min) was calculated. The concentrations causing death after 15 minutes exposure were recorded and the LC_{50} (15-min) was calculated. A range of concentrations was used such that the no effect concentration, the 100% effect concentration and several in-between concentrations were determined. [Details of actual concentrations are not provided].
Result:	Isobutane caused CNS stimulation. Signs of intoxication were slight tremors of the limbs, marked tremors of the limbs and head, convulsions, narcosis, shallow respiration and death from respiratory depression. Recovery from a non-lethal exposure was rapid and the rats appeared normal within 10 minutes. Where death occurred, it was during exposure, never afterwards. The calculated EC_{50} and LC_{50} values with 95% confidence limits, expressed as concentrations in air are as follows: EC_{50} (CNS stimulation, 10 min.) 200000 (160000-230000) ppm [≡ 475,444 (380,355-546,760) mg/m^3] LC_{50} (15 min.) 570000 (480000-650000) ppm [≡ 1,355,015 (1,141,065-1,545,192) mg/m^3]
Reliability:	2, valid with restrictions. Study not performed to guidelines and some experimental details lacking.

(6)

5. Toxicity

Type:	LC_{50}
Species:	rat
Sex:	no data
Exposure time:	4 hour(s)
Value:	658 mg/l [≡ 658g/m^3]
Year:	1969
GLP:	no data
Test substance:	Butane, no further specification
Method:	Method not described, dose levels, group sizes, observation period not specified. LC_{50} stated to be estimated by Litchfield & Wilcoxon method.
Result:	Study was conducted to determine butane levels in several organs. Butane was found in brain, kidney, liver and perinephric adipose tissue.
Reliability:	3, invalid. Study not performed to guidelines and some experimental details lacking.

(24)

Type:	LC_{50}
Species:	mouse
Sex:	no data
Exposure time:	2 hour(s)
Value:	680 mg/l [≡ 680 g/m^3]
Year:	1969
GLP:	no data
Test substance:	Butane, not specified further
Method:	No details given of experimental conditions.
Result:	Confidence limits given as 596-775. LC_{50} value and limits determined by method of Litchfield & Wilcoxon.
Reliability:	3, invalid. Study not performed to guidelines and some experimental details lacking.

(24)

Type	EC_{50}
Species:	dog
Exposure time:	5 minute(s)
Year:	1982
GLP:	no data
Test substance:	Propane and isobutane
Method:	Method not described, but reference given to previous publication by authors which does include a description of the method.
Result:	EC_{50} for cardiac sensitization to adrenaline in dogs after 5 mins. exposure to propane and isobutane are given below. Values given are the EC_{50} expressed as concentration in air (ppm) with 95% confidence limits. Propane 180000 (120000-260000) [Equivalent to 324,640 (216,427-468,925) mg/m^3] Isobutane 70000 (47000-106000) [Equivalent to 166,405 (111,729-251,985) mg/m^3]
Reliability:	4, not assignable. Inadequate description of study.

(6)

Type: cardiac sensitization to epinephrine
Species: dog
Vehicle: air
Exposure time: 10 minute(s)
Year: 1948
GLP: no data
Test substance: Ethane, propane, n-Butane, iso-Butane

Method: Electrocardiograms, Lead II, were recorded from the unanaesthetised dogs. Epinephrine hydrochloride solution (1:100000) was injected i.v. at a dose of 0.01 mg/Kg over a 25 to 40 second time interval. After administration of the epinephrine HCl another ECG was taken. Each animal was subsequently permitted to breathe a mixture of hydrocarbons in varying concentrations (15 to 90%) mixed with oxygen. After 10 minutes' inhalation of the hydrocarbon an ECG trace was made following administration of epinephrine HCl as described above.

Result: Sensitisation of the myocardium occurred at the following incidence:

Hydrocarbon	No. of dogs sensitised/No. exposed
Ethane	2/4
Propane	3/3
n-Butane	2/2
iso-Butane	2/2

The authors reported the results with 12 different hydrocarbons. Only those of relevance to this dossier are summarised here.

Remark: This work is an experimental study carried out as part of a programme to examine the usefulness of different materials as anaesthetics. Although not a guideline study, it nevertheless demonstrates the potential of some hydrocarbons to sensitise the myocardium to epinephrine.

Reliability: 4, not assignable

(15)

5.1.3 Acute Dermal Toxicity

Not applicable

5.1.4 Acute Toxicity, other Routes

Not applicable

5.2 CORROSIVENESS AND IRRITATION

5.2.1 Skin Irritation

Not applicable. However, evaporation of liquefied petroleum gas from the skin will cause cold burns.

5.2.2 Eye Irritation

Species:	rabbit
Concentration:	undiluted
Test substance:	Butane
Remark:	The following statement is made in Grant's Toxicology of the Eye, under the heading Butane: "Butane is an essentially non-toxic petroleum gas which causes no disturbance of the eye, even when injected into the anterior chamber experimentally in rabbits. I found it disappeared spontaneously from the eye in two to four days, causing no disturbance." No other details are provided.
Reliability:	3, invalid. This is an unreliable piece of anecdotal information and should not be used in an evaluation of the eye irritancy potential of butane.

(12)

5.3 SENSITIZATION

Not applicable

5.4 REPEATED DOSE TOXICITY

Species:	rat
Sex:	male/female
Strain:	Fischer 344
Route of administration:	inhalation
Exposure period:	90 days
Frequency of treatment:	6 hours/day, 5 days/week
Post. observation. period:	None
Doses:	0, 1017 & 4489 ppm [≡ 0, 2709 & 11,959 mg/m^3]
Control Group:	yes, concurrent no treatment
NOAEL:	4489 ppm
Method:	OECD Guide-line 413 "Subchronic Inhalation Toxicity: 90-day Study"
Year:	1986
GLP:	no data
Test substance:	Two mixtures were tested as follows: n-butane/n-pentane 50/50 wt.% isobutane/isopentane 50/50 wt.% The mixtures were prepared by gravimetrically filling gas cylinders with 50lb. of each component and then compressing the cylinders to 250 psi. The components were 99% minimum purity.
Test condition:	Inhalation exposures were conducted in Rochester-type 1m^3 stainless steel chambers. Test atmospheres were achieved by flash evaporation of the liquid phase components as they were released from the storage cylinders. Hydrocarbon concentrations in the chambers were monitored and adjustments made as necessary in order to achieve the desired atmospheres.
Method:	20 male and 10 female six-week-old rats were exposed to each concentration, 6 hours each day for 5 days each week. Total duration of the study was 90 days. A negative control group of 40 male and 20 female rats were exposed to filtered air under otherwise similar conditions. The rats were observed daily throughout the study, were weighed weekly and immediately prior to sacrifice. Necropsies were performed on half the male rats in each treatment group after the 20th exposure and for the remaining animals at the conclusion of the 90-day study. At necropsy, the presence of lesions and other abnormal conditions was noted and liver and kidney weights determined. Major tissues, except for kidneys were collected and fixed, but not examined microscopically. Kidneys were fixed and examined histologically.
Result:	There were no mortalities in the study. Possible treatment-related but NOT dose-related effects included transient hunched posture and/or lethargy and intermittent tremor. Statistically significant decreases in body weight occurred in both sexes by weeks 3 and 4 when exposed to the n-butane/n-pentane mixture. Recovery occurred by the end of the study for males but not for the females. There were no treatment-related gross lesions observed, nor were there any kidney or liver weight changes following exposure. Nephrotoxicity was observed after 20 exposures in males at both dose groups of the butane/pentane mixture but this had disappeared by 90 days. A similar effect was seen in males after 20 exposures to 1000 ppm of the isobutane/isopentane mixture, but again this was not apparent in the rats exposed for 90 days. The authors concluded that although there had been a

slight nephrotoxic response in male rats after 20 exposures, this was transient and was not present after 90 days exposure.

It is concluded, therefore that the NOAEL (concentration) is 4489 ppm.

Reliability: 1, valid without restriction

Remark: The purpose of this study was to examine the possible nephrotoxic effects of C_4 and C_5 hydrocarbons present in gasoline. Due to the limited scope of the study, organ weight measurements were restricted to kidney and liver and histopathological examinations also restricted to the kidney.

(2)

5.5 GENETIC TOXICITY 'IN VITRO'

Type: Ames test
System of testing: Salmonella typhimurium, reverse mutation assay using strains TA98, TA100, TA1535, TA1537 & TA1538.
Concentration: Concentrations ranging between 1 to 50% in air.
Metabolic activation: with and without
Result: negative
Method: OECD 471, modified to test gaseous substances
Year: 1980
GLP: no data
Test substance: Gases of the following 6 compositions were tested:

n-Butane	99.7%
iso-Butane	0.3%
iso-Butane	96.3%
n-Butane	3.8%
Propane	0.3%
Propane	>99.9%
iso-Butane	trace
n-Butane	trace
iso-Pentane	97.2%
n-Pentane	2.8%
n-Pentane	98.7%
cycloPentane	0.6%
cis-Pentane-2	-
iso-Butane	97.4%
n-Butane	2.19%
Propane	0.4%
Ethane	0.01%

Method: Duplicate plates seeded with the respective Salmonella strains (with and without S9 fractions) were placed in desiccators from which air was withdrawn and replaced by the gases under test. Test concentrations were 10, 20, 30, 40 and 50% in air.
The plates were exposed for 6 hours to the gas mixtures in the sealed desiccators, after which time they were removed and incubated at 37°C for an additional 40-45 hours. The number of histidine revertants were counted and recorded. Negative and positive (methylene chloride) controls were also carried out. Rat S9 fractions were used for metabolic activation.

Result: The positive control (methylene chloride) was mutagenic in strains TA98 and TA100 and was slightly mutagenic in TA1535.

Neither n-butane, iso-butane nor propane were toxic or mutagenic at any of the concentrations tested.

Iso pentane was toxic at concentrations of 10% and above. Further studies were carried out at 1, 2, 5 and 8% and no mutagenicity was found at these lower concentrations.

n-Pentane was toxic at concentrations of 25 and 50%. Further studies were carried out at 1, 2, 5, 8 and 10% and no mutagenicity was found at these non-toxic concentrations.

Iso butane was weakly toxic at a concentration of 50% but was not mutagenic at concentrations of 5, 10, 20, 30 or 40%.

In conclusion, none of the hydrocarbons were mutagenic with or without metabolic activation in the Ames Salmonella assay in 5 strains exposed for 6 hours in desiccators.

Reliability: 1, valid without restriction

(14)

5.6 GENETIC TOXICITY 'IN VIVO'

No data

5.7 CARCINOGENICITY

No data

5.8 TOXICITY TO REPRODUCTION

No data

5.9 DEVELOPMENTAL TOXICITY/TERATOGENICITY

No data

5.11 EXPERIENCE WITH HUMAN EXPOSURE

During laboratory investigations of workers bottling liquefied propane and butane, most of the workers complained of respiratory symptoms, e.g. dry cough and dry throat together with gastrointestinal effects. The electrocardiographic findings in some workers indicated sinus tachycardia, extrasystole and incomplete right bundle branch block.

(5)

Lactic acid production in workers experiencing propane "poisoning" has been reported as slight.

(5)

Eight adult volunteers of both sexes were exposed to isobutane in a controlled-environment chamber to monitor their physiological responses to a series of gas concentrations ranging from 250 to 1000 ppm [≡ 594-2377mg/m^3].
Initially, the response to exposure periods of 1 and 2 minutes, and 1, 2 and 8 hours were studied. Since there were no untoward responses, the eight volunteers were then exposed repetitively to isobutane at a concentration of 500 ppm [≡ 1189 mg/m^3] for 1, 2 or 8 hours a day, five days a week for 2 weeks. This was followed by studying the effects of exposure to 2 mixtures of isobutane and propane for 1, 2 or 8 hours a day for 2 days. During the studies, the subjects were kept under strict medical surveillance.
No untoward subjective or physiological responses were recorded either during or after the exposures. Special attention was placed on evaluating cardiac and respiratory effects by the use of continual ECG telemetry and computerised spirometric measurements. Additionally, the following serial laboratory investigations were unaltered by the exposures: complete blood count, urinalysis, serum alkaline phosphatase, SGOT, LDH, serum bilirubin, blood sugar, serum calcium, serum phosphorus, BUN, spontaneous EEG, visual evoked responses, a battery of cognitive tests and an ACTH stimulation test.

(26)

Ikoma records 20 cases of sudden death in which propane and propylene were found in the blood, urine and cerebrospinal fluids of the victims.

(13)

6. References

1. ACGIH (1998) Threshold limit values and Biological exposure indices for 1998-90. Cincinnatti, Ohio: American Conference of Governmental Industrial Hygienists.

2. Aranyi, C., O'Shea, W.J., Halder,C.A., Holdsworth, C.E. and Cockrell, B.Y. (1986).
   Absence of hydrocarbon-induced nephropathy in rats exposed subchronically to volatile hydrocarbon mixtures pertinent to gasoline.
   Toxicology and Industrial Health, vol. 2 No. 1, pp 85-98

3. Atkinson, R. (1985)
   Kinetics and mechanisms of the gas-phase reactions of the hydroxyl radical with organic compounds under atmospheric conditions.
   Che. Rev. Volume 85, pp 69-201

4. Atkinson, R. (1990)
   Gas-phase tropospheric chemistry of organic compounds: a review.
   Atmospheric Environment Vol. 24A, pp 1-41

5. Aviado, D.M., Zakhari, S. and Wanatabe, T. (1977)
   Non-Fluorinated propellants and Solvents for Aerosols.
   CRC Press, Cleveland, Ohio.

6. Clark, D.G. and Tinson, D.J. (1982)
   Acute Inhalation Toxicity of some Halogenated and Non-Halogenated Hydrocarbons.
   Human Toxicol. Vol. 1, pp 239-247.

7. CMA (1999)
   Robust summary of information on Group 1: High butadiene C4

8. CRC Handbook of Chemistry and Physics, 10th Edition. (1990-1991)

9. EU (1999)
   Draft environmental and health risk assessment of Butadiene.

10. Fuerst, R. and Stephens, S. (1970)
    Studies of effects of gases and gamma irradiation on Neurospora crassa
    Dev. Ind. Microbiol. Vol. 11, pp 301-310

11. Gas Processors Association (1996)
    Table of Physical Constants of paraffin Hydrocarbons and Other Components of Natural Gas.
    Gas Processors Association standard 2145-96

12. Grant, W.M. (1974)
    Toxicology of the eye, 2nd edition. Charles C. Thomas, Springfield, Ill.

13. Ikoma, T. (1972)
    Nichidai Igaku Zasshi, Vol. 31 No. 2. pp 71-

14. Kirwin, C.J and Thomas, W.C. (1980)
    In vitro microbiological mutagenicity studies of hydrocarbon propellants.
    J. Soc. Cosmet. Chem. Vol. 31., pp 367-370

15. Krantz,J.C., Carr, J. and Vitcha, J.F. (1948)
    Anesthesia XXXI. A study of cyclic and non cyclic hydrocarbons on cardiac automaticity.
    J. Pharm. Exp. Therap. Vol 94, pp 315-318

6. References

16. Lewis, R.J. (1992)
Sax's Dangerous Properties of Industrial Materials. Eighth edition, van Nostrand Reinhold, New York

17. Log Pow database. Pomona College, 1993

18. Mackay, D., Patterson,S. and Shiu, W.Y. (1992)
Generic models for evaluating the regional fate of chemicals.
Chemosphere Vol. 24, pp 695-717

19. Mackerer, C. R. and Galvin, J. B. (1999)
The toxicology of nine light petroleum hydrocarbons
J. Tox. And Env. Health, Vol. 58, Numbers 1-2, September 10-24, 1999

20 McKee, R., Frank, E., Heath, J., Owen, D., Przygoda, R., Trimmer, G. and Whitman, F. (1998)
Toxicology of n-Pentane (CAS no. 109-66-0)
J. App. Toxicol. Vol. 18,pp431-442

21 O'Brien, W.E. and Brown, L.R. (1967)
The catabolism of isobutane and other alkanes by a member of the genus Mycobacterium.
Dev. Ind. Microbiol. Vol. 9, pp 389-393

22 Rode, L.J. and Foster, J.W. (1965)
Gaseous hydrocarbons and the germination of bacterial spores
Microbiology, Vol. 53, pp 31-38

23 Sandmeyer, E.E. (1981)
Aliphatic hydrocarbons
Chapter 45 in Patty's Industrial Hygiene and Toxicology, Third revised edition. Volume 2B Toxicology. Pages 3175-3220. John Wiley & Sons. New York

24 Shugaev, B.B. (1969)
Concentrations of hydrocarbons in tissues as a measure of toxicity.
Arch. Environ. Health Vol. 18, pp 878-882

25 Stephens, S., De Sha, C. and Fuerst, R. (1971)
Phenotypic and genetic effects in Neurospora crassa produced by selected gases and gases mixed with oxygen.
Dev. Ind. Microbiol. Vol. 12, pp 346-353

26 Stewart, R.D. Herrmann, A.A., Baretta, E.D., Forster, H.V, Sikora, J.J., Newton, P.E. and Soto, R. J. (1977)
Acute and repetetive human exposure to isobutane.
Scand. J. Work Environ. & Health Vol. 3, No. 4, pp 234-243

27 van Zandt, P.T.J and van Leeuwen, C.J. (1992)
A proposal for priority setting of existing chemical substances.
Report prepared for the European Commission.

28 Vestal, J.R. and Perry, J.J. (1970)
Effect of substrate on the lipids of the hydrocarbon-utilizing *Mycobacterium vaccae*
Can. J. Microbiol., vol. 17, pp 445-449

29 Wanatabe, K. and Takesue, S. (1971)
Effect of some hydrocarbon gases on egg white lysosyme activities on different substrates
Enzymologia, Vol. 41, pp 99-111

6. References

30 ZoBell, C.E. (1963)
The occurence, effects and fate of oil polluting the sea.
Int. J. Air Wat. poll. Pergamon Press Vol. 7, pp 173-198.